ADJUSTING DYNAMICALLY THE RESOLUTION IN DISCRETE SIMULATIONS

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ABSTRACT

Simulation models can be modelled on different levels of detail. Models with a high resolution describe the real system more exactly. But a high resolution is often contrary to the fast execution of a simulation. In some cases the execution of large simulations in real-time is impossible in a high resolution.
If a simulation is visualized during its execution, the viewer does not pay equal attention to each part of the simulation. In this paper an approach is presented which simulates models in high resolution only at places with a high visual focus. In case of a changed visual focus, the resolution of the simulation will be dynamically adjusted. This leads to the perception of a completely high-resolution simulation without the necessary computing time. But on the other hand a less detailed simulation at places with a lower visual focus must be accepted. Thus the movements of the viewer influence the execution of the simulation. In this paper solutions for sub-problems as well as the results of a prototype are presented.

1 INTRODUCTION

Simulations in a high resolution require a long execution time. In large models with a high resolution this can lead to an execution, which is slower than in real time. The use of parallel computing systems provides more computing power and thus permits an acceleration of the computation. The problem however is thereby only shifted to another level.
However the execution would be much faster if the mayor part of the simulation is realized on a rough level and only small parts are simulated in a high resolution.
The viewer does not pay equal attention to every detail. In this project a method and a prototype have been developed in order to provide the viewer with the feeling of a high resolution without executing the whole simulation in detail and with lower computing efforts. With this prototype only the part the viewer is looking at will be simulated in high resolution. Remote objects or objects that cannot be seen by the viewer are simulated in a lower resolution.
If the viewer changes his position or angle of view, it will be necessary to specify the objects, which then (after the change) are lying in the field of vision. Objects that are lying outside the field of vision will be simulated in a lower resolution (more aggregated). They must be aggregated. This takes place dynamically during the execution. The user gets the illusion of a simulation in high resolution in every place, which would possibly cause too much computing efforts if a complete simulation took place. But an inexact calculation of those parts, which are not located within the visual focus of the user has to be accepted. This leads to inexact simulation results.

2 RELATED WORK

While many algorithms, which dynamically change the level of detail of objects stimulated by the users view, were developed in the visualization sector, such methods are only rare known in simulation technique so far.

2.1 Simulation

There exist series of examinations for modelling, maintaining and coupling models in different resolutions (cp. Davis, Paul and Bigelow 98 or Reynolds and Natrajan 97). These approaches do not use the user view as stimulation for changing the resolution of individual objects during the execution time. Their goal is not to reduce calculation time. Systems changing dynamically the resolution during the simulation stimulated by the users view are only marginally known for special applications (e.g. Carlson and Hodgins 97). The results are hardly applicable to the general modelling, dynamic and resolution variable simulation of discrete models.

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2.2 Visualization

The use of different models as well as dynamic exchanges stimulated by the users view for the same object have already been known for a long time in visualization systems (e.g. Clark 76). If an object is far away from the viewer, he can only see an rough model. However, if the viewer comes closer to the object, better models gradually replace this model. Other objects which move further away from the users are replaced by more aggregated representatives. The viewer gets the impression of a completely high detailing while at the same time a substantial reduction of the polygons takes place.

3 PROBLEMS

In a simulation many problems arise from the vision of a dynamically changing resolution depending on the visual focus of the viewer. Modelling methods for such systems must be developed. In the viewer position the viewer must be given a visual cut, his input data must be processed and of this a variation of the resolution must be dynamically produced (stimulated). If such stimulations are created, model states must be calculated in an aggregated or more detailed direction.

3.1 Modelling

Before executing a model, this model has to be created. To use different resolutions of one object during the execution, different models (one for each resolution) for the same object are needed. This leads to new modelling problems.

3.2 User interaction

The user can move free within the three-dimensional environment and should be enabled to influence the simulation by his movements. Depending on his movements, detailing and aggregation processes shall be triggered off. In order to make this possible, his movements have to be continuously registered and the resulting data has to be transferred from the user interface to the simulation and from the simulation to the user interface.
If the visual focus of the user changes, the resolution of the objects can change. For this purpose, fast calculation methods are required to calculate the objects, which have to change their resolution. A detailing or aggregation process has to be stimulated, if the resolution of an object changes.

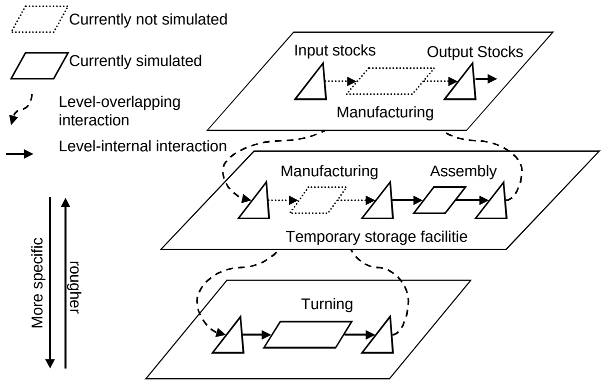

Figure 2: Example of a hierarchical detail-variable simulation model

3.3 Dynamic detailing

If an object has to be simulated in a higher resolution, also the state of the object has to be described in more details and a more detailed state has to be generated from a less detailed one. Up to this moment it is not absolutely necessary to forward the complete information for the calculation of the detailed state, intelligent methods have to be developed for this purpose. While e.g. in case of an assembly-line in an aggregated resolution the number of parts on it may be enough to describe the state, the exact position of each part may be important in case of a high resolution. However, this position is not available during a simulation in an aggregated resolution. This leads to a lack of information. Other object types require other detailing methods. If a new object type is added to the system, the modeller must have the possibility to specify a suitable detailing method by himself. For this purpose different methods are presented in section 4.2.

3.4 Dynamic aggregation

If the user's visual focus of an object decreases, the object has to be simulated in a lower resolution. The detailed representative serves for calculating the state of the less detailed representative. Since the aggregation type is directly connected with the object type, these methods are specific for object types. The requirements for dynamic aggregation are similar to those for "dynamic detailing".

4 TECHNIQUE

4.1 Modelling

Two methods can be differentiated (implicit and explicit resolution variable specific modeling) to build dynamic variable specific simulation models.

IMPLICIT RESOLUTION VARIABLE SPECIFIC MODELLING

The implicit variable specific modelling enables the user to create models on the same level on which he has built models with the respective simulation tool so far. He chooses objects from a building set, adds these to the model and combines them. The model can be interpreted as done before if these objects are not variable specific types. But if the user utilizes implicit variable specific types, submodels in a higher resolution according to the employed object automatically have to be generated. If the more specific model should be simulated with another simulator, an object for this purpose has to be created in the other simulator. Deleting the aggregated object, at the same time each more specific object has to be destroyed automatically to avoid the generation of "corpses".

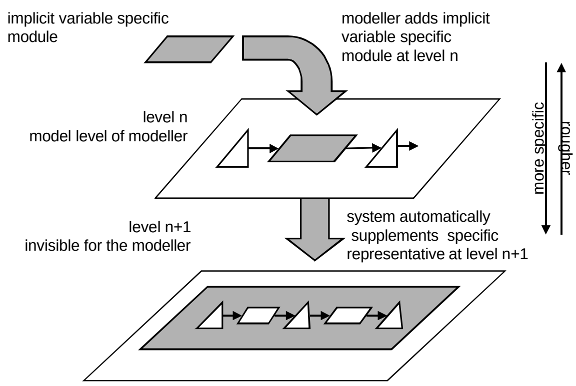

Figure 3: Implicit resolution variable specific modelling

The data transfer, the production of representatives for the more specific simulation, as well as the required methods for detailing/aggregation, are encapsulated in these types. In this option the modeler had the possibility to built his model "traditionally", however, he obtains a variable specific model that extends itself over various simulators.

EXPLICIT RESOLUTION VARIABLE SPECIFIC MODELLING

If the modeller wants to create resolution variable specific types himself, he must explicitly generate new types that support this.
The modeler must state the methods, how the objects should be simulated more specific or more aggregated. In each case he must implement a type for both options.
In addition, he has to implement the techniques for the transfer of the aggregated states into a detailed state and vice versa the techniques for the generation of the aggregated state out of the detailed one.
By using implicit variable specific types at the specific level, hierarchies can be developed.

4.2 Dynamic aggregation/detailing

After getting a detailing event a object has to calculate a state of the more detailed representative. We are proposing various methods for this:

- **Post-simulation**: To determine the condition of the more specific object, an state in the past is taken and simulated alone with the source data of the aggregated object, that has appeared since the state in the past has been calculated. If this is a long time the state will be in good conditions. With this method computing time can only be saved, if the user looks only at parts of the model.
- **Direct calculation**: The modeler knows the more specific as well as the aggregated model. This knowledge can be used to create methods how to calculate systematically the specific condition out of the aggregated one. This must be done by the modeler. Maybe further information about the running time of the aggregated object (e.g. the time of entry of the object) should be collected. Example: A production line is described with a parallel machine on the rough level and as lining up of the individual machines on the detailed level. If the model is in the rough condition and a detailing event enters, the parts of the parallel machine can be relocated depending on the past operating time to the respective machines of the more detailed level.
- **Freezing**: If the objects have already been simulated in high resolution, the condition of the specific object can be frozen and taken back at another detailing. It is not necessary to collect or transfer information between the levels. This method requires only little computing time, however, it contains high inaccuracies. It is appropriate for objects that rarely change their condition. Thus it should only be used for objects that rarely change their condition.

The same methods can be used vice versa for aggregation. All these methods premise that the more specific object works also in the aggregated mode. If this is not guaranteed, an aggregation message has to be sent to it at first.
If a component enters into the object that is simulated more specifically, this component has to be transferred to the more specific simulation. Maybe the part possesses more attributes at the more specific level. Methods for their generation have to be modeled. The equivalent is true for the transfer of specific objects to less specific levels. For this purpose a framework and some examples are implemented into the prototype.

4.3 Stimulation of detailing/aggregation

The production of specification or the inverse process must be stimulated from the visualization.
Different indicators are supposed to be used (and combined) for measuring the intensity of the user attention of certain objects:

- **Distance**: Objects that are far away have a lower user attention. Only this method has been realised in the prototype discussed later.
- **Occlusion**: If there is another object (e.g. a wall) between the viewer and the object, the object is invisible for the user. So the user attention is low. If the visualisation is calculation this, it can be used.
- **View direction**: The viewer cannot see objects that are in his back. Those objects have a lower user attention than the objects in front of him.
- **Logistical stimulation**: Objects, being influenced via a logistic chain (e.g. preliminary machines) by objects with a high user attention, get a higher logistical focus.

4.4 Implementation

In a detailing variable model several representatives and descriptions of conditions can exist for single objects on different levels. At a point in time however only exactly one representative and a description of condition are active for each object. The change between the different representatives and descriptions of conditions is stimulated from the visualization as described in section 4.3. For the initialisation of the system it is sufficient to initialise the conditions on the roughest level and to activate those detailing simulations depending on the starting position of the user.

5 RESULTS

A prototype has been developed that partly verifies the process.
This example illustrates a simulation of three plants. After starting the simulation the user is far away from all plants. Each plant has a low visual focus so that all are simulated on the most aggregated level by a parallel machine and visualized by a big white cube (compare figure 3).

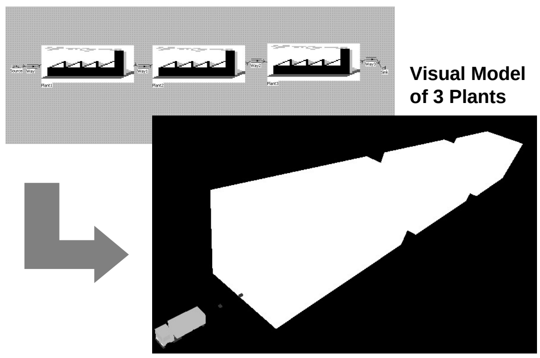

Figure 3: Simulation in low resolution

The viewer approaching a plant initiates a detailing. The plant and only this plant is no more simulated by a parallel machine but by a more specified model. In this case, the plant is simulated by 4 lines of which each 2 are switched in line. In the visualization, the representative of the production lines replaces the 3-D-representative of the plant (figure 4).

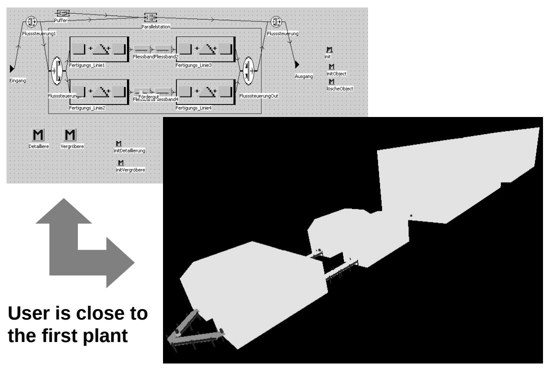

Figure 4: Detailed Simulation of one Plant

The viewer coming closer to these production lines experiences their next detailing. Hence the simulation of the machines in the production lines takes place in another simulator. The representatives of the machines of the lines are substituted by more detailed ones (figure 5).

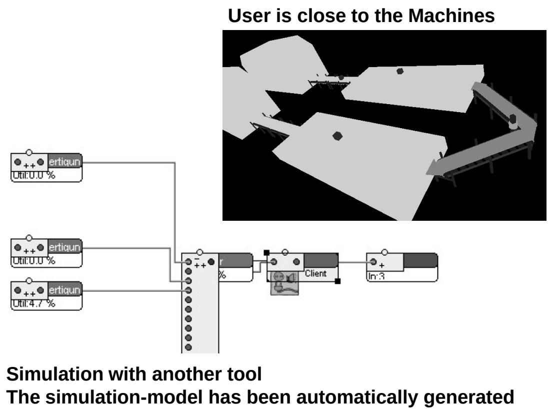

Figure 5: Simulation in highest resolution of two machines using a different simulator

If the user once again departs or moves into a simulation zone of another part model, the respective detailing/aggregation is updated.

6 CONCLUSION

This project demonstrated that a dynamic adjusting of the resolution during the execution of a simulation is possible. A prototype has been build.

A modelling method has been developed. If the modeller only uses already existing modules, models can be developed with a comparable effort as done conventionally (implicit resolution variable specific modelling). Additional efforts are needed in case of designing new level overlapping classes (explicit resolution variable specific modelling).

Various methods for the generation of more specific/aggregated conditions have been presented. Several indicators for the stimulation of specifications/aggregations have been proposed.

Finally the user walks virtually through the model and everything close to him is simulated with models in high resolution. Parts of the model that are far away from him are simulated with lower resolution. This reduces the necessary calculation time. But the user gets the impression of a complete detailed simulation.

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